# Euclid and WFIRST AFTA

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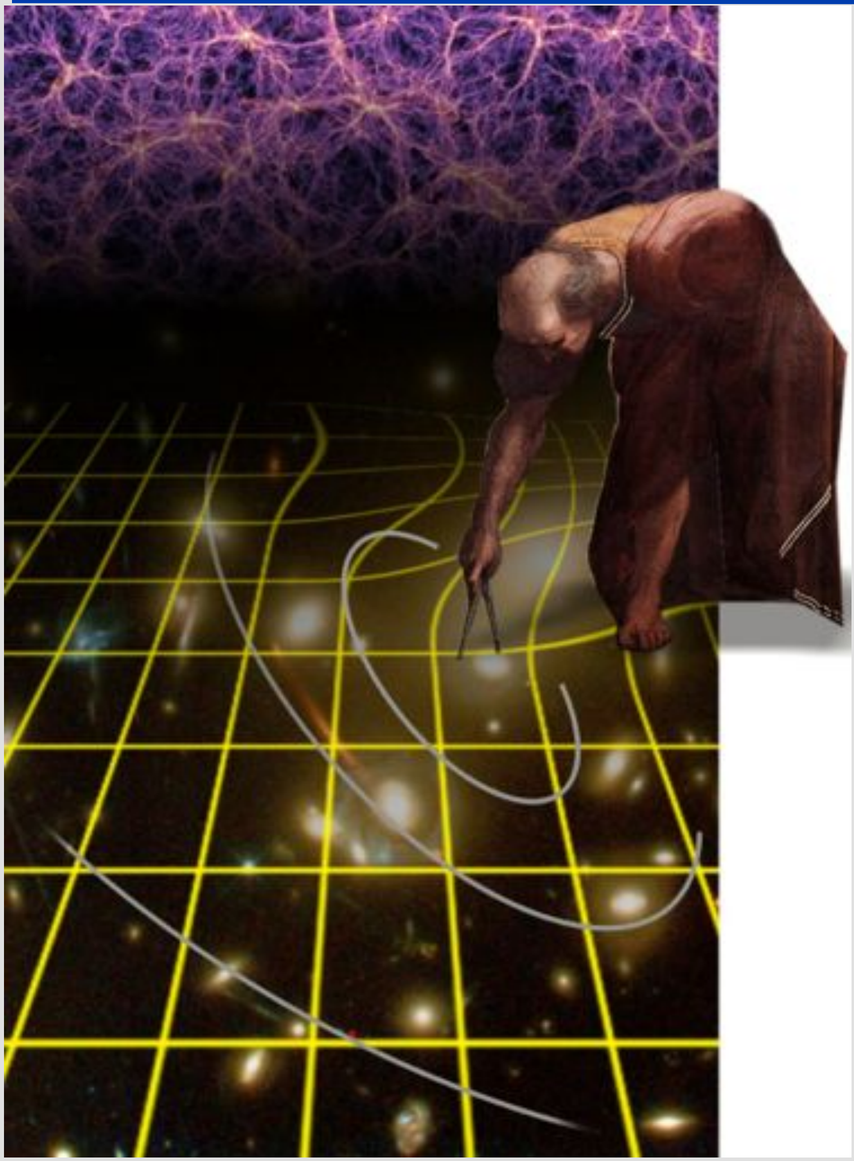
**WFIRST SDT**



# Euclid

Mapping the geometry of the Dark Universe

2004: Dark Universe Mission proposed as a Theme to ESA's Cosmic Vision programme

Oct 2007: DUNE and SPACE jointly selected for an ESA Assessment Phase

April 2010: Formation of single Euclid Consortium

2010-2011: Definition phase

July 2011: Final Euclid Proposal- Red Book

**Oct 2011: Cosmic Vision Approval of Euclid**

**June 2012:** Official selection of Euclid and start of implementation

**Fall 2012**: NASA Joins, selects 40 US participants for funding

2012-2020: Implementation phase

2020: launch

2020-2026 :science operations

# Euclid goals

***Understand the nature of Dark Energy and Dark Matter by:***

•Measuring the DE equation of state parameters $w_0$ *and* $w_a$ to a precision of 2% and 10%, respectively, using both expansion history and structure growth.

•Measuring the growth factor exponent $\gamma$ with a precision of 2%, enabling to distinguish General Relativity from the modified-gravity theories

•Testing the Cold Dark Matter paradigm for structure formation, and measure the sum of the neutrino masses to a precision better than 0.04eV when combined with Planck.

•Improving by a factor of 20 the determination of the initial condition parameters compared to Planck alone.

Responsive to **some** of the *scientific* goals outlined in NWNH Panel Reports:

- How did the universe begin?
- Why is the universe accelerating?
- What is dark matter?
- What are the properties of neutrinos?

# Euclid concept

- **Optimized for two complementary cosmological probes:**
  - **—Weak Gravitational Lensing**
  - **—Galaxy Clustering (Baryonic Acoustic Oscillations & Redshift Space Distortions)**

  **Additional probes: clusters, ISW**

  **15,000 square degree survey**

  **—Imaging (WL):**
    - **High precision visible imaging at (shapes)**
    - **NIR Photometry (photo-z)**
    - **Near Infrared Spectroscopy (Galaxy Clustering)**

- **SN, exoplanet microlensing not part of science goals now**
  - **—Possible, but not planned**

# Euclid Mission Baseline

Mission elements:

- L2 Orbit
- 6.25 yr primary mission
- Telescope: three mirror astigmat (TMA) with 1.2 m primary
- Instruments:

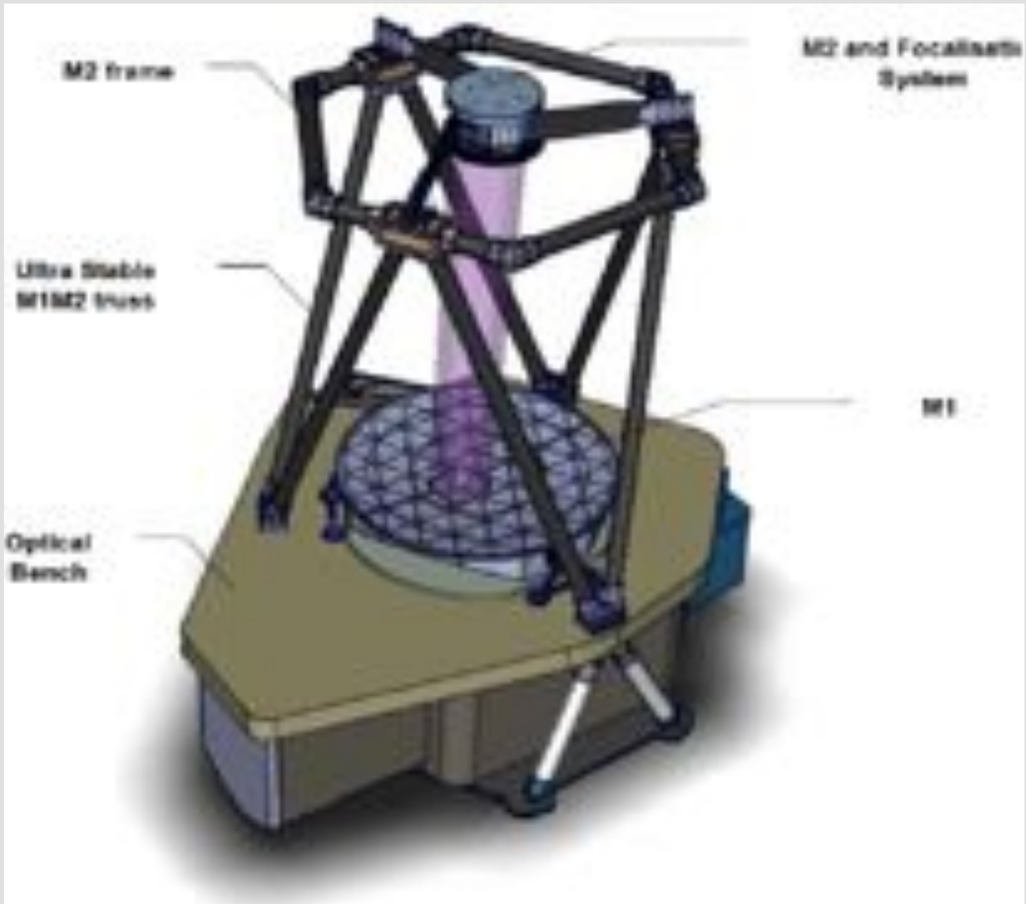
– VIS: Visible imaging channel: 0.5 deg$^2$, 0.10'' pixels, 0.16'' PSF FWHM, very broad band r+i+z (0.5-0.9mu), 36 CCD detectors, galaxy shapes

– NISP: NIR channel: 0.5 deg$^{2,}$

  – 16 HgCdTe detectors, 1-2mu:
    - Photometry: 0.3'' pixels, 3 bands Y,J,H, photo-z's
    - Spectroscopy: slitless, R=500, redshifts

From NASA

# Euclid Payload concepts




Thales Alenia Space (240K telescope)


Astrium (150K telescope)

# Euclid Mission

| SURVEYS in 6.25 yrs | | |
|---|---|---|
| | Area (deg2) | Description |
| Wide Survey | 15,000 $\mathrm{deg}^2$ | Step and stare with 4 dither pointings per step. |
| Deep Survey | 40 $\mathrm{deg}^2$ | In at least 2 patches of > 10 $\mathrm{deg}^2$<br>2 magnitudes deeper than wide survey |

N+S?
Obs strategy?

| PAYLOAD | | | | | |
|---|---|---|---|---|---|
| Telescope | 1.2 m Korsch, 3 mirror anastigmat, f=24.5 m | | | | |
| Instrument | VIS | NISP | | | |
| Field-of-View | 0.787×0.709 $\mathrm{deg}^2$ | 0.763×0.722 $\mathrm{deg}^2$ | | | |
| Capability | Visual Imaging | NIR Imaging Photometry | | | NIR Spectroscopy |
| Wavelength range | 550- 900 nm | Y (920-1146nm), | J (1146-1372 nm) | H (1372-2000nm) | 1100-2000 nm |
| Sensitivity | 24.5 mag<br>10σ extended source | 24 mag<br>5σ point source | 24 mag<br>5σ point source | 24 mag<br>5σ point source | $3\,10^{-16}$ erg cm-2 s-1<br>3.5σ unresolved line flux |
| | Shapes + Photo-z of $\underline{n}$ = 1.5 x$10^9$ galaxies ? | | | | $z$ of $n$=5x$10^7$ galaxies |
| Detector Technology | 36 arrays<br>4k×4k CCD | 16 arrays<br>2k×2k NIR sensitive HgCdTe detectors | | | |
| Pixel Size<br>Spectral resolution | 0.1 arcsec | 0.3 arcsec | | | 0.3 arcsec<br>R=250 |

**TBD: SN and/or μ-lens surveys**

Ref: Euclid RB arXiv:1110.3193

# Schedule

- October 4, 2011 : Euclid selected as ESA M2 Cosmic Vision
- Spring 2012 : Completion of the Definition phase (A/B1)

- June 2012 : Adoption for the Implem. Phase (B2/C/D/E1)
- November 2012 : Industrial Partner Selected
- 
- Q1 2014 : Instrument PDR
- Q3/Q4 2017 : Flight Model delivery

- **Q2 2020 : Launch (L)**
- <(L+6 months) : Start Routine Phase
- L+7 yrs : End of Nominal Mission
- L+9 yrs : End of Active Archive Phase

# Euclid Science Reach

| | Modified Gravity | Dark Matter | Initial Conditions | Dark Energy | | |
|---|---|---|---|---|---|---|
| **Parameter** | $\gamma$ | $m_\nu/eV$ | $f_{NL}$ | $w_p$ | $w_a$ | *FoM* |
| Euclid Primary | 0.010 | 0.027 | 5.5 | 0.015 | 0.150 | 430 |
| Euclid All | 0.009 | 0.020 | 2.0 | 0.013 | 0.048 | 1540 |
| Euclid+Planck | 0.007 | 0.019 | 2.0 | 0.007 | 0.035 | 4020 |
| Current (09/2011) | 0.200 | 0.580 | 100 | 0.100 | 1.500 | ~10 |
| **Improvement Factor** | **30** | **30** | **50** | **>10** | **>50** | **>300** |

Euclid addresses many aspects of the current cosmological paradigm

From Euclid Red Book :
*sci.esa.int/science-e/www/object/index.cfm?fobjectid=48983*

# Euclid, WFIRST and NWNH

- Euclid alone can ***NOT*** meet all the goals of the decadal survey, and WFIRST will likely be limited by multiple scientific goals
  - Observing time limited in ~ 5years
  - e.g., WFIRST DRM1/2 do not cover the WL area we would like or Astro2010 recommended
- Disparate goals require a wide range of capabilities and sufficient survey time
  - Properly complementary Euclid and WFIRST can provide this
  - Together the missions will maximize progress on NWNH goals
- Euclid primary mission also allows going beyond the *observational* goals of WFIRST to other *scientific* goals outlined in NWNH Panel Reports:
  - How did the universe begin?
  - Why is the universe accelerating?
  - What is dark matter?
  - What are the properties of neutrinos?

Euclid Goals (Red Book):

1. DE FoM
2. Growth/GR
3. DM/neutrinos
4. Inflation

# Euclid and WFIRST

- Euclid and WFIRST should be largely complementary in capability
  - —Some overlap in capability is acceptable, but as envisioned in NWNH, WFIRST will have *unique* capabilities not duplicated by Euclid or LSST
  - —Independent, complementary approaches towards difficult and ambitious science is desirable, even necessary, to maximize progress
  - —~10 years of observing time is needed to properly address NWNH goals
  - —Together Euclid and WFIRST can advance the observational **AND** the theoretical goals of NWNH
- Slightly phased (2020/~2025) approach may prove beneficial
  - —WFIRST can benefit from early Euclid observations and attack most compelling/difficult questions
  - —tune WFIRST observing strategies based on early data from Euclid
  - —Longer baseline enhances WFIRST (μlensing)
  - —High quality WFIRST data may enhance Euclid science return (WL)

# Euclid and WFIRST

- In studying DE, FoM does not tell the whole story
  - —Multiple probes from multiple observatories with different possible systematics are necessary
  - —If Euclid is systematics-limited in WL, higher quality WFIRST data may leverage the survey

- Systematics are the key for DE
  - —This is a primary reason we go to space
  - —WFIRST and Euclid will be sensitive to different systematics, with WFIRST having the advantage
  - —All WFIRST designs make multiply redundant WL shape measurements which Euclid will not do

# Ways AFTA is less Complementary than DRM1/2

- **Wavelength range – AFTA is unlikely to be able to get to 2.4$\mu$m**
  - —Will have a wavelength cutoff closer to Euclid's
  - —Lower redshift range for BAO, SN
  - —Less wavelength coverage for ancillary science
- **AFTA is an obscured optical design**
  - —Will not have the PSF simplicity of an unobscured design
  - —More difficult to reach WL systematics goals
  - —Won't see the 'full benefit' of going to 2.4m diameter in terms of PSF size and throughput

# Euclid/NEW synergy for dark sector

- Higher throughput of a 2.4m mirror makes SN survey at z>1.3 possible
    - Could use whatever SN Euclid does (if any) as a starting point
- Euclid will NOT do a SN survey competitive with what WFIRST could do

- Higher throughput means better sampling for BAO
    - Could still go to somewhat higher *z* than Euclid

- And IFU would significantly increase complemtarity

# Summary: Extragalactic Surveys

From Chris Hirata

| | WFIRST DRM1 | WFIRST DRM2 | Big Telescope |
|---|---|---|---|
| Implementation | 1.3 m unobs<br>36 H2RG<br>0.18"/p | 1.1 m unobs<br>14 H4RG<br>0.18"/p | 2.4 m obs<br>20 H4RG<br>0.0975"/p |
| Imaging Survey* [4 filters for all; depths are 5σ isolated pt src] | 0.92—2.40 μm<br>26.0—26.2 mag AB<br>2800 $deg^2$/yr<br>EE50 = 0.15—0.21" | 0.92—2.40 μm<br>25.8—26.0 mag AB<br>2900 $deg^2$/yr<br>EE50 = 0.18—0.25" | 0.92—2.17 μm<br>26.9—27.3 mag AB<br>1080 $deg^2$/yr<br>EE50 = 0.11—0.14" |
| Weak Lensing [reddest 3 filters] | 30, 33, 32 gal/$am^2$ | 24, 26, 25 gal/$am^2$ | 79, 82, 72 gal/$am^2$ |
| Redshift Survey [≥7σ Hα detections] | z = 1.28—2.66<br>4900 gal/$deg^2$<br>2900 $deg^2$/yr | z = 1.59—2.66<br>2900 gal/deg2<br>4400 $deg^2$/yr | z = 1.13 – 2.20<br>4900 gal/$deg^2$<br>4000 $deg^2$/yr |

* The big telescope could in principle support an accelerated imaging mode matching the WFIRST DRM1 survey rate of 2800 $deg^2$/yr. This reaches depth of 25.8—26.0 mag AB and 26/31/32 galaxies per $arcmin^2$. This survey is heavily read noise limited (90 s exposures) so may not be the best use of a big telescope.

# WL: A completely different regime

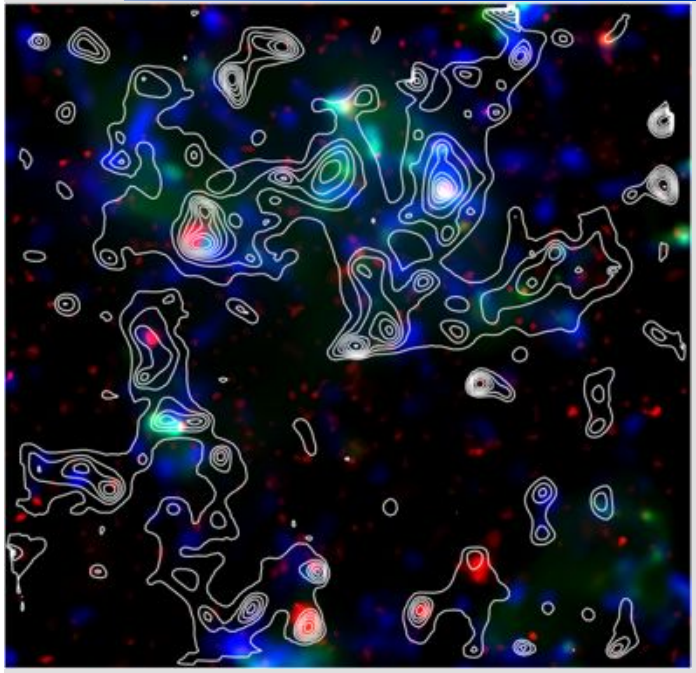
- WL with AFTA survey would reach >80 galaxies per square arcminute
  — vs ~30 with DRM1/2 and Euclid, and even fewer from the ground

- With a deeper survey AFTA could reach HUDF depths of >300 galaxies per square arcminute

***This is a fundamentally different WL regime that is not possible from the ground or with a 1.3 meter class telescope due to PSF size.***

- Does not necessarily help with DE FoM (wide>deeper for FoM)
- Much better calibration data
- *Much* better for understanding dark matter

# HST-like imaging over 1000s of square degrees



COSMOS: Dark Matter Mapping

Bullet Cluster: Evidence for collisionless CDM

CLASH: Cluster Masses and Strong Lensing

These studies are enabled by high resolution and a high surface density of resolved galaxies. This is not possible with a ~1.3 m class mirror.

See also recent z>10 galaxy from CLASH!

# Microlensing & Exoplanets

- **Euclid unlikely to devote significant time to microlensing for technical and programmatic reasons**
- **Longer baseline afforded by 2 missions**
- **Higher resolution of AFTA better for smaller planets**
- **Better characterization of host stars and higher percentage of detections that allow mass determinations (via proper motion)**
- **Also for exoplanets- see coronagraph capabilities**